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REAL TIME DISPLAY OF THE VERTICAL BEAM SIZES IN LEP USING THE BEXE X-RAY DETECTOR AND FAST VME BASED COMPUTERS

Jones, R.; Manarin, A.; Pignard, C.; Rossa, E.; Schmickler, H.; Sillanoli, M.; Surback, G.

CERN – Geneva - CH

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Fast X-ray detectors based on CdTe photoconductors have been installed in LEP since the beginning of its operation in 1989. The angular divergence of the high energy photons from the synchrotron radiation (x-rays) and the narrow spacing of the 64 photoconductors of the detector allow a good measurement of vertical beam profiles down to an rms beam size of 300 μm.

This paper presents some specific parameters and experimental results of an upgrade program in which the local processing power of the front-end electronics has been increased by a factor 50. Such a powerful tool has allowed a real time display of the time evolution of the vertical beam sizes. An online correlation plot between the electron and positron beam sizes (turn by turn) is also displayed.

These online video images are available in the LEP control room and are used in daily operation for luminosity optimisation.

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1. PRINCIPLE OF THE DETECTOR

The vertical beam sizes in LEP are measured, in single shot, by a photoconductive device known as the BEXE detector. A detailed description of this detector can be found in references [1] to [6]. Figure 1 gives an overview of the whole system. The synchrotron X-rays emitted by the bunches give an image of the vertical beam profile via the 64 channels of the detector [3]. All these signals are digitised by 8 bits Flash ADCs. The digitised raw data are used in two ways. One set is sent to the old master crate working with a 68k-CPU. This produces a PAL video image, which was used by the main control-room for daily operation during the commissioning of the slave crate. A copy of the data is also sent to the new slave crate, which uses a Power-PC running under LYNX-OS for the data analysis. This increases the processing power by a factor 50. The raw-data are analysed very quickly and sent through a dedicated video channel to the main-control room, thus providing a real time display of the results.

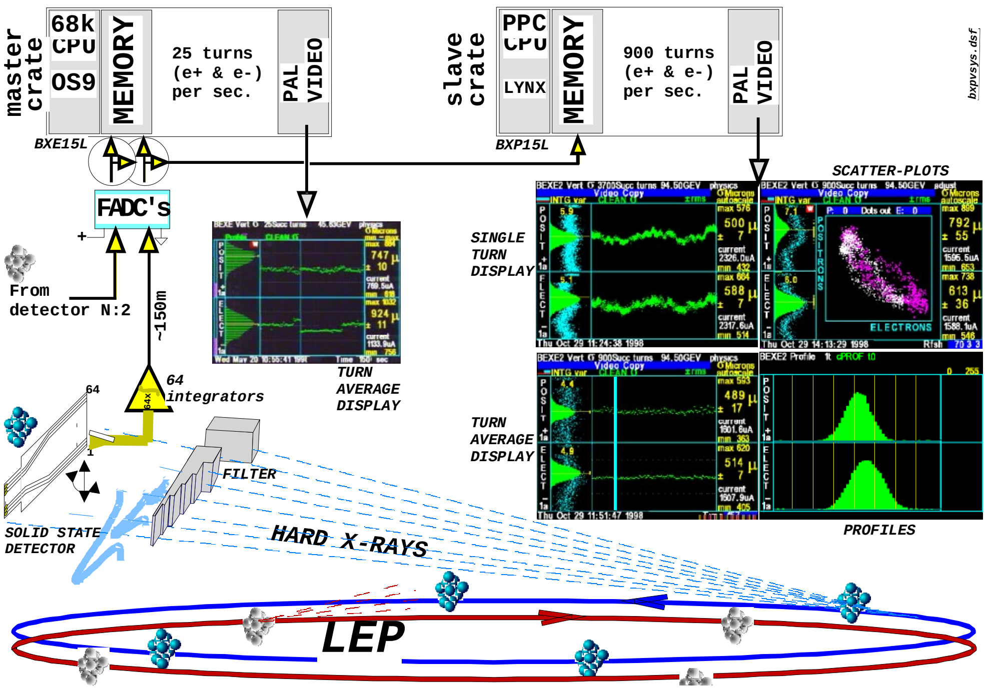

Figure 1: Synoptic of the whole.

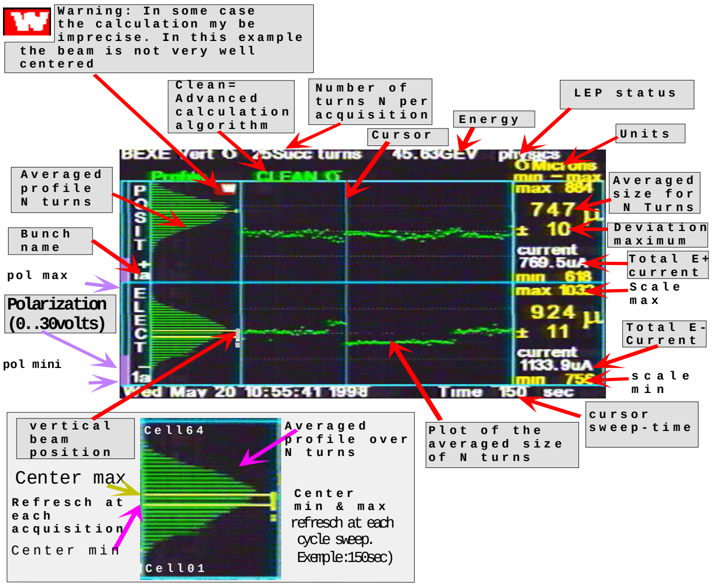

Figure 2: Explanation of the video signal displayed in the main-control room.

2. REAL TIME DISPLAYS

Several different real time displays are possible. The operator makes the selection from the main control room via an easy to used graphical interface, which is described in more detail later on.

2.1. History of the bunch size

The size of electrons and positions bunches are displayed on the same screen simultaneously. Figure 2 is a copy of the video image available for the operator. The image is updated in real time with the cursor moving from the left to right, to create a history of the beam size.

2.2. The BEXE Graphical Interface

The BEXE detector is controlled via a graphical user interface running under the UNIX operating system.

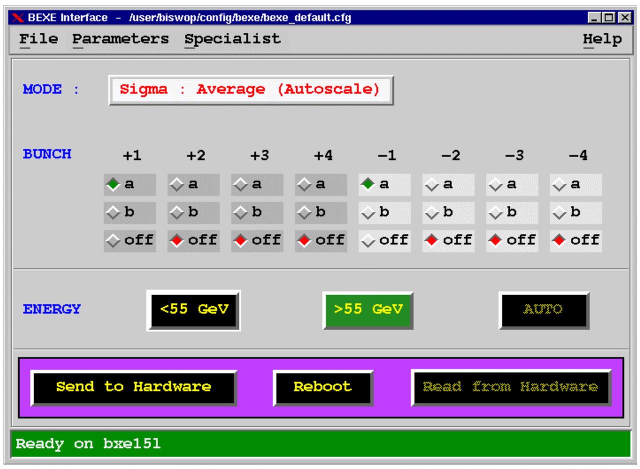

Figure 3: The main BEXE graphical interface.

The main display, shown in Figure 3, provides the operator with a simple way of changing the BEXE settings for different machine conditions. The display mode determines the type of analysis that is displayed in real-time on the operation console. Available display modes include:

Bunch History - shown in figure 2. This mode is used during physics runs to optimise the luminosity by minimising the vertical beam size of both the electron and positron beams. The main interface also allows the operator to select the bunch or bunches for which the analysis is to be carried out and hardware settings.

Scatter Plot - This plots the electron beam size history against the positron beam size history, and has been used to study the effect of beam-beam interactions. Such a plot is shown in Figure 1, where the interaction is seen as a correlation between electron and positron bunch sizes, which results in the elliptical scatter plots.

Bunch Profiles - Here the actual beam profile measured by the BEXE detector is displayed. This mode is used for the calibration described in section 3.

3. CALIBRATION OF THE DETECTOR

In order to obtain an accurate representation of the vertical beam profile, a calibration of each pixel is required. The two procedures developed for the calibration of the 64 channels and their associated chain of front-end electronics are described in the following sections.

3.1. Gain calibration using a Gain Scan

This calibration procedure involves scanning the detector vertically across the beam and recording the beam profile at several positions. Typically 64 acquisitions are made by moving the detector in steps of 100 µm, which corresponds to the distance between each channel. An off-line calibration extracts the relative gain for the 64 channels by comparing the peak amplitude for each channel. Since such a calibration scan requires some minutes for completion, it is sensitive to the beam instability. The procedure is therefore always carried out during a stable physics run, with the intensity of the beam logged for each acquisition. After a calibration, these gains are cross-checked by applying them in the real-time analysis, and verifying that the beam is the same for all vertical positions of the detector.

3.2. Gain calibration by Gaussian Fits

Historically this method was the first tested with the beam. Only few acquisitions were made, with the beam profile centred at the top, middle and bottom of the detector. Then the program performs a gaussian fit on each profile, from which it extracts the relative gains for each channel. The disadvantage of this method is the difficulty in normalising the gains between the different profile positions and also its inability to give a good fit at the edge of the detector.

3.3. Comparison of the two methods

Figure 4 shows the relative gains for each of the 64channels of the detector calculated using both calibration methods. A good agreement is seen in the central region, while large differences exist at both ends of the detector, where the gaussian fit becomes less valid.

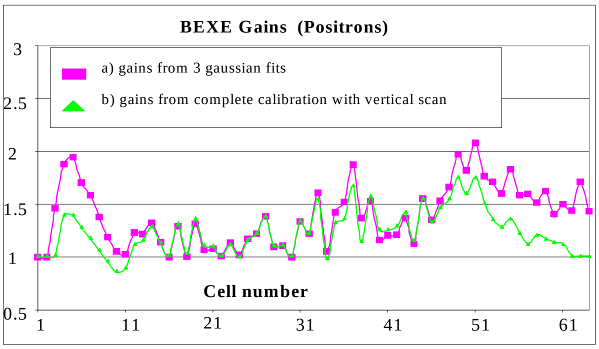

Figure 4: Comparison of the results obtained by the two methods of calibration.

The calibration of the LEP BEXE detectors will therefore be carried out two to three times a year.

4. ONLINE BEAM SIZE CALCULATION

In addition to applying the gain coefficient to each channel, the algorithm used in the calculation of the beam size also has to take into account noise sources. Stepping motor low frequency noise was found to introduce a pedestal on the data, the slope of which could change from turn to turn. The algorithm used in the original 68K CPU therefore had to strike a balance between speed and precision to allow a fast calculation of the bunch size. A straightforward fit of a gaussian curve proved to take too long for on-line calculation and therefore the analysis was performed in the following way:

1) Apply the calibration gain-coefficients to each channel.
2) Calculate the RMS value, mean value, and centre of gravity of the profile.
3) Filter the data with a filter that becomes stronger the further the cells are from the centre of the profile.
4) Calculate the pedestal (slope and offset) for each profile.
5) Calculate the final RMS value after the subtraction of the pedestal.

These calculations were tested with simulated data using random noise and a random pedestal. A precision around one per cent in the RMS compared to the sigma value was found for noise levels of the same order of magnitude as those found in LEP.

Figures 5 and 6 show the results of the turn-by-turn calculation of the rms and centre of gravity of the beam profile respectively. The vertical beam size have a standard deviation of less than 3 microns for the most stable beam measured in LEP. The same is also true for the vertical position (centre of gravity of the beam), where the fluctuations are again in the order of a few microns in single-shot measurement.

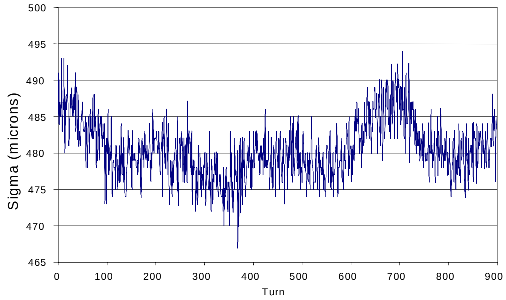

Figure 5: The turn by turn calculation of the beam size.

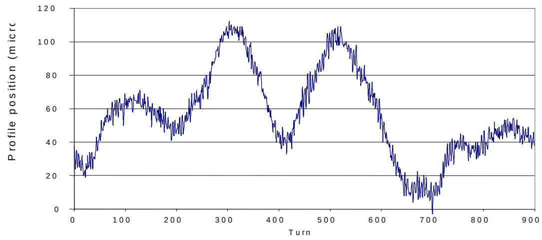

Figure 6: The turn by turn calculation of the centre of gravity of the beam profile.

5. CONCLUSION

The BEXE X-ray detectors have proved to be an invaluable tool for luminosity optimisation in LEP. The detectors are capable of withstanding extremely high radiation doses (>10^{14} Gray). The addition of power PC based analysis software has allowed the detectors to be exploited for real-time applications such as:

- Luminosity optimisation using the real-time display of the evolution of the vertical beam sizes.
- The study of beam-beam interactions using the scatter plot correlation display of electron and positron beam sizes.

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